DOCUMENT RESUME

ED 104 860 SP 009 098

AUTHOR Cleminson, Ronald W.; And Others
TITLE Guidelines and Competencies for Elementary Science Education: A Course Module.
INSTITUTION MSS Information Corp., New York, N.Y.
PUB DATE 74
NOTE 88p.
AVAILABLE FROM MSS Information Corporation, 655 Madison Avenue, New York, New York 10021 ($3.75, 20 percent discount in orders of $200.00 or more)

EDRS PRICE MF-$0.76 HC-$4.43 PLUS POSTAGE
DESCRIPTORS Curriculum; Elementary Education; *Performance Based Teacher Education; *Performance Criteria; *Science Instruction; *Teacher Education; *Teaching Skills

ABSTRACT

This three-part document contains a set of competencies for elementary science teachers. The objectives state the level of competency expected and suggest how it may be achieved. The first section, "Process-Inquiry Skills," discusses competencies fundamental for elementary teachers and children. The second section, "Instructional Skills," is designed to help teachers develop skills in planning for and teaching elementary school science by the inquiry approach. The third section, "Interest and Research/Curriculum Knowledge," provides the background in science education necessary to support this approach to teaching and to nurture an interest in science. Instructions for completing each competency are contained in a module. Students are responsible for selecting activities or methods included in the modular framework to complete each competency satisfactorily. (Authors/JS)

ED104860

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

PERMISSION TO REPRODUCE THIS COPYRIGHTED MATERIAL HAS BEEN GRANTED BY
MSS Info. Corp.
TO ERIC AND ORGANIZATIONS OPERATING UNDER AGREEMENTS WITH THE NATIONAL INSTITUTE OF EDUCATION. FURTHER REPRODUCTION OUTSIDE THE ERIC SYSTEM REQUIRES PERMISSION OF THE COPYRIGHT OWNER

GUIDELINES AND COMPETENCIES FOR ELEMENTARY SCIENCE EDUCATION:

A Course Module

By
Ronald W. Cleminson
Nelle E. Moore
Paul L. Jones
Memphis State University

MSS Information Corporation
655 Madison Avenue, New York, N.Y. 10021

SP009 098

Copyright © 1974
by MSS Information Corporation
All Rights Reserved

CONTENTS

Preface 5

Introduction 7

GUIDELINE A: Process-Inquiry Skills **9**

A1 — Observing and Inferring 11

A2 — Classifying 25

A3 — Measuring 29

A4 — Recognizing and Controlling Variables 36

A5 — Organizing Data 43

A6 — Hypothesizing 52

A7 — Replicating 59

GUIDELINE B: Instructional Skills **61**

B1 — Identifying and Classifying Measurable Performance Objectives 63

B2 — Comprehending the Basic Principles of Inquiry (Discovery) Teaching 69

B3 — Designing and Constructing an Inquiry Activity Module 71

B4 — Teaching by Means of Inquiry or Discovery 74

GUIDELINE C: Interest and Research/Curriculum Knowledge **77**

C1 — Demonstrating Interest 79

C2 — Demonstrating Knowledge 81

C3 — Describing and Comparing Programs 83

C4 — Analyzing Children's Responses 90

Bibliography 93

PREFACE

The merging in time of two incidents gave impetus to the development of this volume--ground work for a competency-based program in the College of Education, Memphis State University, and the publication of the 1970 edition of Preservice Science Education of Elementary School Teachers by the American Association for the Advancement of Science. The earlier edition (1963) had served as the basis for a reorganization of the science content courses for preservice education of elementary teachers.

The current AAAS recommendations (1970) furnished the actual organizational pattern for the guidelines presented in this volume. The developers felt that the spirit of inquiry and emphasis on scientific processes contained in the AAAS guide expressed their own viewpoint in elementary science education. It seemed appropriate also to turn to another AAAS publication, Science--A Process Approach: Commentary for Teachers, for background information and some explanatory activities in developing the portion of this volume which deals with scientific processes.

For three years these guidelines in various stages of development have served as the basic framework for our undergraduate elementary science methods course. The feedback provided by our students has resulted in numerous revisions of the guidelines. The developers would like to thank our students, who have been so patient and understanding of us as they struggled with the earlier versions of these guidelines.

GUIDELINES AND COMPETENCIES FOR ELEMENTARY SCIENCE EDUCATION: A COURSE MODULE

The following guidelines contain a minimum set of competencies which the instructors believe all elementary science teachers should possess. The objectives state the level of competency expected and suggest how they may be achieved. Instructions for completing each competency are contained in the module.

The module provides students with a framework for achieving each competency. The student is responsible for selecting activities and/or methods to complete satisfactorily each competency, as well as maintaining a loose-leaf notebook of his progress in the course. The instructor's role is that of instructional manager-teacher. Students will meet with the instructor individually and/or in small groups during the academic period. Individuals are responsible for scheduling these meetings with the instructor.

The first section, Process-Inquiry Skills (A), contains the competencies which the instructors believe are fundamental for elementary teachers and children. They are appropriate for students at all levels and provide a basis for developing process-inquiry skills.

The second and third sections deal with Instructional Skills (B) and Interest and Research/Curriculum Knowledge (C), respectively. These sections have been designed to help the teacher develop skills in planning for and teaching elementary school science by the inquiry (discovery) approach (B), and to provide the background knowledge in science education necessary to support this approach to teaching, and to nurture an interest in science (C).

The instructors suggest that the competencies in Guideline A be completed before those in Guideline B. The competencies contained in Guideline C may be completed at any time during the academic period.

GUIDELINE A

PROCESS-INQUIRY SKILLS

The science experiences for elementary teachers should develop competence in inquiry skills and processes of scientific inquiry.

A 1 OBSERVING AND INFERRING - The student will distinguish between observations and inferences and will demonstrate his ability to make reasonable inferences.

A 2 CLASSIFYING - The student will construct a classification scheme for a set of objects which differ in three or more ways.

A 3 MEASURING - The student will demonstrate the measurement of length, mass, force, temperature and volume in arbitrary, English and metric units.

A 4 IDENTIFYING AND CONTROLLING VARIABLES - The student will be able to identify the variables which affect the results of investigations and describe how and why they are or are not controlled.

A 5 ORGANIZING DATA - The student will collect and organize data and describe the rationale for the organization (describing, diagramming, tabulating, graphing, etc.).

A 6 HYPOTHESIZING - The student will construct a hypothesis, test its validity, and on the basis of the results obtained from testing either accept the hypothesis or reject and modify it.

A 7 REPLICATING - The student will replicate an experiment and compare the results obtained with those in the original experimentation.

SELF-EVALUATION--PROGRESS SCALE

In order to determine your present competency level for process-inquiry skills, please read the competencies A1 through A6. Place a "B" in the appropriate column to indicate your beginning competency level.

At the end of the course, place an "E" in the appropriate column to indicate the degree of competency you feel you possess. This self-evaluation will enable you to visualize your growth toward the attainment of each competency.

	I have no knowledge of this competency.			I am familiar with the competency and feel I have an adequate understanding of the concept.			I fully understand the competency and can utilize and/or relate it to my science teaching.		
	1	2	3	4	5	6	7	8	9
A1									
A2									
A3									
A4									
A5									
A6									
A7									

A1 - OBSERVING AND INFERRING

General Competency

The student will distinguish between observations and inferences and will demonstrate his ability to make reasonable inferences.

Performance Criteria

Given information and appropriate activities the student will:

A1.1 distinguish between observations and inferences.

A1.2 demonstrate his ability to make observations and reasonable inferences on the basis of these observations.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. Read "Observing" and "Inferring."
2. Complete the cartoon series entitled "Inference Cartoons." See the instructor for response sheet.
3. Arrange with the instructor to complete additional activities.
4. When you feel you have met the performance criteria, date and initial the Competency Completion Checklist which the instructor will provide.

BEST COPY AVAILABLE

A1 - NOTES AND COMMENTS FOR OBSERVING AND INFERRING

The process of observing is basic to the development of all other skills. Observations are fundamental to any scientific investigation; these observations in turn lead to the construction of inferences or hypotheses that can be tested by observational techniques. So, observing provides both a basis for new inferences and hypotheses and a tool for testing existing inferences and hypotheses.

In preparing to report any observation, consider these basic ideas:

1. Observations include more than just seeing.
2. Observations should be quantitative whenever possible.
3. Statements of change are important observations.
4. Observations should be separated from inferences.

1. In Science--A Process Approach, for the process of observing, any one or several or all of the senses--sight, touch, hearing, taste, and smell--may be used. Observing requires that you pick up objects, feel them, shake them, press them, and do all the things which help you obtain information about the object. It does not mean visual inspection alone.

2. Quantitative observations (those that tell "how much") usually communicate more information than qualitative observations. Compare these two statements:

"The room was rather large."

"The room was rather large. It measured 9 meters by 13 meters."

The second statement tells the exact size of the room; it is more precise. The first statement is open to interpretation. The listener does not know whether the room is large enough to be a warehouse or not. Exact measurements are quantitative observations. However, estimations or comparisons also clarify observations. Speaking of the same room referred to in the above statements you could say, "The room was about 10 meters by 14 meters," or, "It was about the size of an apartment living room." Both statements communicate something about "rather large."

3. In observing it is important to notice the things that are changing. Compare characteristics before, during, and after the change. Observe the rate of change and the circumstances under which the change is observed. What happens if heat or a liquid is introduced? How long does it take for the change to occur?

4. By observation we mean those characteristics that are directly perceived by the senses; an inference involves an interpretation of direct observations. For example, we may see a doctor going into the Jones' house and say, "Mrs. Jones is sick." This is an inference--we observed the doctor entering the house, we inferred that Mrs. Jones was sick. Obviously, there are other possible explanations for the doctor's visit. For example, it might have been Mr. Jones or one of the children who was sick....

In conclusion, review these questions when you make observations:

1. Have you observed the appearance of the shape, color, number, position, order, and so on? Have you observed any odor or taste or sound? Tap or shake the object if necessary. Did you feel the object to determine its weight? The lack of sound, taste, or odor is important, too, and should be stated.

So, whenever possible, make observations with all your senses.

2. Have you asked questions like "how much length?" Do you use terms like bright, loud, small, tiny, big, many, tall, and others without saying exactly how loud or small or bright?

So, whenever possible, state your observations in quantitative terms.

3. Did you compare the object before, during and after the change for similarities and differences? Did you observe the rate of change in appropriate units--seconds, minutes, days, and so on?

Does the object you are observing change? What are the changes and how do they occur?

4. Did you limit your observations to properties which were perceived by the senses? Did you ask yourself, "Did I really observe that?" (AAS, 1968, pp. 35ff).

Nothing is more fundamental to clear and logical thought than the ability to distinguish between an observation and an inference that is made about an observation. Many pitfalls in logical thinking can be avoided if this distinction is continually made and used.

An observation is a personal experience that is obtained through one of the senses. An inference is an explanation of an observation and results from thinking about the observation. The thought process is frequently strongly conditioned by past experiences, and may take place in a fraction of a second. For example, you may be in your living room and see a bright flash outside the window. Almost immediately after the flash you hear a loud crashing noise. In less than a second you may begin to state your inference, "Lightning struck something not very far away." This inference is an explanation of two observations--light and sound. It is based on past experience with lightning and thunder including the knowledge that the time interval between the flash and the sound is a measure of how far away the lightning struck. Do you suppose that your immediate reaction might have been to make a different inference about the flash of light and the loud noise if you had been a marine just returned home from Vietnam?

In many cases it is possible to make more than one inference to explain an observation or set of observations. It is important to remember this. Think how many times you have "jumped to a conclusion," that is, accepted the first inference you thought of, to explain an observation, only to find out later that your inference was not supported by further observations.

For example, suppose that it is recess. You look out the window and see David and Neal playing catch with a softball. You go back to your desk, and in a few moments there is a crash of broken glass as a ball goes through the window and rolls across the floor. You jump up, see David and Neal running away, and call through the broken window, "David and Neal, come in here this instant." In half a minute they appear in your room and you begin to lecture them about running away from the scene of an accident. Both boys protest that they did not break the window and David produces the softball that he has been holding behind his back as evidence that the window was not broken by the ball that they had been playing with. Only then do you retrieve the ball that came through the window from under a desk and find that

it is a golf ball. And there is a golf course just across the street from the school. What new inference would you make based on this further information?

The "hot line" between Washington and Moscow was constructed to decrease the chances that either the United States or Russia would jump to a conclusion (inference) about some international incident and act too hastily on the basis of that inference.

Magicians carefully cultivate the art of inducing the audience to jump to a conclusion with one hasty inference to explain an observation. The audience sees the magician reach into a tall silk hat and "pull-out" a rabbit, a balloon, and several other large objects. They are expected to infer that those objects were in the hat before the magician "pulled them out."

Scientists cultivate the ability to make at least one, and frequently more than one, carefully thought out inference to explain an observation or set of observations.

Central to all scientific investigations are the activities stated in the objectives. Scientists make observations, construct several inferences about each set of observations, and decide what new observations would help support the inferences. They then make these new observations to see whether each of the inferences is an acceptable explanation (AAS, 1968, pp. 145 ff).

INFERENCE CARTOONS

Directions: Study the following cartoons and then read the following questions. Decide which statements are observations and which statements are inferences. Answer questions on the response sheet provided by the instructor.

Questions for Cartoon I

The ground is wet.
The tricycle has water drops on it.
It rained while we were sleeping.
Maybe Mother watered the lawn.
With what sense was the observation made?
Can you decide, from what you are told, who is correct?
What will you do to find out?

Questions for Cartoon II

The bike felt wet.
Now it is dry.
The water evaporated. It went into the air.
Mother dried the bike.
What kinds of observations were made?

Questions for Cartoon III

I hear a noise.
I hear clomp, clomp.
It must be Dad.
It could be the mailman.
With what sense was the observation made?

Questions for Cartoon IV

I hear a siren.
I hear sounds like fire engines clanging.
There must be a fire.
No, I think they are in the 4th of July parade.
I smell smoke.
What kinds of observations were made?

Questions for Cartoon V

Look at the pile of dirt.
Here is a hole.
I can put my foot in the hole.
That pile of dirt came from the hole.
Mother put the pile of dirt there.
A wild animal dug the hole.
What kinds of observations were made?
Do you know which boy is right?

Questions for Cartoon VI

I am hot.
It is hot today.
Daddy's wheelbarrow is hot.
The metal slide must be too hot to sit on.
The slide isn't hot.
It is in the shade.
With what sense was the observation made?
(Adapted from AAAS-SAPA, Part D)

Cartoon 1

HEY MIKE, THE GROUND IS WET, YOUR TRICYCLE HAS WATERDROPS ALL OVER IT. IT MUST HAVE RAINED.
I DID NOT SEE ANY RAIN DID YOU SEE IT RAIN, ANDREW?
IT RAINED WHILE WE WERE SLEEPING HOW DID THE BIKE GET WET IF IT DID NOT RAIN?
MAYBE MOTHER WATERED THE LAWN.
I THINK IT RAINED

17

Cartoon II

EARLY THIS MORNING THE BIKE FELT WET
LET ME FEEL THE BIKE. NOW IT IS DRY.
THE WATER EVAPORATED. IT WENT INTO THE AIR.
MOTHER DRIED THE BIKE WITH A TOWEL. THE WATER DID NOT EVAPORATE.

Cartoon III

I HEAR A NOISE!
WHAT?
LISTEN!
YES I HEAR CLOMP, CLOMP
BE QUIET IT MUST BE DAD
IT COULD BE THE MAILMAN

Cartoon IV

I HEAR A SIREN
4TH OF JULY
I HEAR SOUNDS LIKE FIRE ENGINES CLANGING
THERE MUST BE A FIRE
CLANG! CLANG!
4TH OF JULY
4TH OF JU
I SMELL SMOKE!
LET'S GO!
No, I THINK THEY ARE IN THE 4TH of July PARADE
4TH of JULY

Cartoon V

LOOK AT THAT LITTLE PILE OF DIRT IN OUR YARD
WHERE?
OH YES, LOOK AT THE PILE OF DIRT.
HERE IS A HOLE
I CAN PUT MY FOOT IN THE HOLE
THAT PILE OF DIRT CAME FROM THE HOLE.
A WILD ANIMAL DUG THE HOLE!
NO! MOTHER PUT THE PILE OF DIRT THERE.

Cartoon VI

WOW, I'M HOT. IT IS HOT TODAY.
WE'RE SITTING IN THE SUNSHINE.
DADDY'S WHEELBARROW FEELS HOT
OUCH! THE WHEELBARROW IS HOT.
THE METAL SLIDE MUST BE TOO HOT TO SIT ON
THE SLIDE ISN'T HOT. IT IS IN THE SHADE.

A2 - CLASSIFYING

General Competency

The student will construct a classification scheme for a set of objects which differ in three or more ways.

Performance Criterion

Given selected activities or a set of objects the student will:

A2.1 construct a classification outline or diagram which has three or more attributes.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. Read commentary entitled "Classifying."
2. Design a classification scheme using suggested materials and construct a classification outline which contains three or more attributes.
3. Arrange with the instructor to complete additional activities (if needed).
4. When you feel you have met the performance criterion (above), date and initial your Competency Completion Checklist.

CLASSIFYING

Classifying is the process scientists use to impose some order on collections of objects or events. Biologists classify organisms as plants or animals. Chemists classify certain substances as acids or bases. Physicists classify subatomic particles by mass, electric charge, and half-life. Astronomers classify stars by magnitude and color. And so on.

Classification schemes are designed to be useful for identifying objects or events. They are also useful for showing similarities, differences and interrelationships. The chemist's periodic table is a good example of this. The periodic table shows families of chemical elements that are related by having similar chemical properties even though the individual elements in each family differ in many other properties such as melting point and boiling point.

Classifying is a process that is not restricted to science. We all classify objects and use classification schemes every day. Stores are classified: grocery, drug, hardware, department, automobile supply, and so on. Businesses of many types are grouped in the classified section of the telephone book.

Books in a library are classified by subject area. There are two major classification schemes used in the United States, the Library of Congress and the Dewey Decimal systems. The former system is most useful for large libraries and the latter for small ones. This illustrates three important principles in classifying. Classification systems are designed to be useful, classification systems are arbitrary, and any group of objects or events can be classified in more than one way.

Developing a classification system is a process in which a set of objects is first divided into two or more subsets on the basis of one observable property. Each subset is further subdivided on the basis of a second observable property, and so on, until individual objects can be identified by observing a sufficient number of properties.

The properties that are used in identifying objects can be put into an outline or a diagram. Such an outline is called a classification key. You may have used a classification key from a book on identifying rocks and minerals, or birds or plants. Many properties may

have to be observed to identify a single object if the set of all objects is large. For example, the classification key in Gray's Manual of Botany lists more than twenty properties that must be observed to identify a particular species of holly (AAAS, 1968, pp. 58 ff).

A3 - MEASURING

General Competency

The student will demonstrate the measurement of length, mass, force, temperature and volume in arbitrary, English, and metric units.

Performance Criterion

Given the resource booklet (available in the bookstore), laboratory equipment, and activities the student will:

A3.1 demonstrate his ability to measure length, mass, force, temperature, and volume in arbitrary, English, and metric units.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. Read "Measuring."
2. Purchase and complete the resource booklet on the metric system.
3. Arrange with the instructor for measuring equipment and for additional activities.
4. When you feel you have met the performance criterion, date and initial you Competency Completion Checklist.

A3 - NOTES AND COMMENTS FOR MEASURING

MEASURING

"When you cannot measure it, when you cannot express it in numbers,-you have scarcely, in your thoughts, advanced to the stage of Science, whatever the matter may be."- Lord Kelvin.

There is much in science that can be learned without measuring, and most scientists would agree that Lord Kelvin overstated the case. However, they would also agree that measuring is one of the skills that is essential for most scientific investigations....

Skill in measuring requires not only the ability to use many measuring instruments properly, but also the ability to carry out calculations with those measurements. In addition, it requires judgment about the appropriate instrument to use for making a measurement (a meterstick is more appropriate than a 30-centimeter ruler for measuring the length of a room), and about when approximate measurements can be used instead of precise ones.

Thousands of types of measuring instruments are used in scientific investigations. The instruments range from simple ones like a ruler to complex and expensive ones like a mass spectrometer....

Figure 1 shows how some quantities may be measured. Note that for items 1-8, each measurement is made with a single instrument, and no computations are required. For items 9-11, the measurements are also made with a single instrument, but a mathematical operation is required to obtain the desired measure. Measurements of this type are sometimes called indirect measurements.

Measurements of speed, density, and heat (items 12-14 in Figure 1) are examples of derived quantities. Note that to obtain measures of each of these quantities, two measuring instruments are used, and mathematical operations are carried out to obtain the measure of the quantity. The units in which derived quantities are expressed may be called derived units. For the derived quantities listed in Figure 1, the derived units are: centimeters per second for speed, grams per milliliter for density, and calories (degrees Celsius per milliliter of water) for heat. Other derived units in the metric system may be used for each of these quantities. The unit that is appropriate depends on what is being measured. The speed of an automobile, for example,

is usually measured in the derived unit kilometers per hour, rather than in centimeters per second.

...Precision refers to the agreement among observed values in repeated measurements. Obviously, if you were to measure the length and width of your classroom by using a meterstick and were to record your results to the nearest millimeter, you would likely not record the same figure each time. You would, however, be able to report a range of values and could with some confidence say that the length or width of the room was a certain value, plus or minus a certain number of millimeters, depending on your techniques in using your meterstick. The smaller the range the greater is the precision of your measurement.

Accuracy, on the other hand, refers to the agreement of the observed measurement with the actual or true value. Actual or true value might be defined operationally as the measurement that is made as carefully as possible with the best measuring instrument that can be made. Accuracy is affected both by the care with which a measuring instrument is used and by the nature of the instrument. For example, if the scale on your meterstick was a bit longer or a bit shorter than a meter, your measurements would not be accurate, even though they might have high precision. Not only are scientists interested in improving the accuracy of their observations, but their ultimate aim is to devise instruments and techniques that will decrease the possible errors (precision) and also be as close as possible to the true value (accuracy).

It is also important in scientific work to use judgment in deciding when to measure precisely and accurately and when to make approximations. An example of a situation in which approximate measurements are satisfactory is found in the exercise, Two Common Gases, Defining Operationally 7, Exercise a, Part G, where a tablespoon is an adequate measure of 15 grams of sodium bicarbonate, and a pile 5 millimeters square on the end of a paste stick is a sufficiently accurate measure of 100 milligrams of manganese dioxide.

Skill in measuring also includes the ability to estimate. The man who guesses your weight at the carnival is highly skilled in estimating weights. Most people do not develop much skill in estimating measurements. You should practice making estimations of length, area, volume, time, mass, and so on....

Finally, you can make estimations to increase the accuracy of measurements. If you are using a thermometer that is graduated in degrees, and if the top of the liquid column is midway between 25° or 26° on the scale, you can estimate that the temperature is 25.5°. Assuming that the scale on the thermometer is properly calibrated --that is, the scale records the true value of temperature--the measurement of 25.5° is more accurate than a measurement of 25° or 26°. Scientists usually try to estimate to the nearest tenth of the smallest scale division of an instrument they are using to make a measurement. With practice, you should be able to do this, too (AAAS, 1970, pp. 85-87).

Please note: Figure 1 that follows was also taken from the above source.

FIGURE 1

Quantity measured	Measuring instrument	Operation performed	Computation	Unit
1. Length	Ruler	Read scale	--	centimeter (cm)
2. Area	Grid	Count squares	--	square centimeter (cm^2)
3. Volume of a liquid	Graduated container	Read scale	--	milliliter (ml)
4. Angle	Protractor	Read Scale	--	degree
5. Temperature	Thermometer	Read scale	--	degree Celsius (^oC)
6. Time	Stopwatch	Read scale	--	second
7. Force	Spring scale	Read scale	--	newton (n)
8. Mass	Equal-arm balance	Count standard masses	--	gram (g)
9. Area of a rectangle	Ruler	Read scale	Multiply length (by width)	cm^2

FIGURE 1 (contd.)

Quantity measured	Measuring instrument	Operation performed	Computation	Unit
10. Volume of a rectangular prism	Ruler	Read scale	Multiply length, width and height	cubic centimeter (cm^3)
11. Volume of an irregular solid	Graduated container of water	Read scale, put object in the water and read scale again	Subtract initial from final scale reading	cubic centimeter (cm^3)
12. Speed	Ruler and stopwatch	Read scale of ruler; read scale of stopwatch	Divide distance traveled by time elapsed	cm/sec
13. Density of a solid	Equal-arm balance and graduated container of water	Count standard masses; measure volume as described in 11	Divide mass by volume	g/cm^3
14. Heat	Graduated container of water and thermometer	Read scale of container, read scale of thermometer before and after changing the temperature of the water	Subtract initial from final temperature, Multiply temperature change by volume of water	calorie (°C/ml of water)

A4 - RECOGNIZING AND CONTROLLING VARIABLES

General Competency

The student will be able to identify the variables which affect the results of investigations and describe how and why they are or are not controlled.

Performance Criteria

Given descriptions of investigations the student will:

A4.1 identify the variables which affect the results of the investigation.

A4.2 describe how and why the variables are or are not controlled.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. Read "Variables."
2. Complete the activity on variables in observing a picture, paying special attention to the comments on the activities.
3. Arrange with the instructor to complete additional activities.
4. When you feel you have met the performance criteria, date and initial your Competency Completion Checklist.

A4 - NOTES AND COMMENTS FOR RECOGNIZING AND CONTROLLING VARIABLES

VARIABLES

You have probably heard a housewife remark following a baking fiasco, "I can't understand why the cake didn't turn out. I did everything exactly the same as I always have." It is reasonable to suspect that something was different, even though the cook did not know it. Perhaps it was an unnoticed change in the ingredients, the length of time the eggs were beaten, the temperature of the butter, the age of the eggs, or any one of a great number of factors. Each of these factors is a variable, which may have influenced the quality of the cake. In this exercise, you will be thinking about variables and how they may influence one another.

The process of Controlling Variables is pervasive in scientific inquiry. The most definitive results of an investigation are obtained when the variables can be identified and carefully controlled. You will have the best possible evidence from your investigations if you follow these steps: Change (manipulate) one variable in a systematic way, and watch for and measure corresponding changes in another (the responding) variable; hold constant (keep the same) all the other variables you can think of while you are manipulating one variable and observing the response of another. It is not always possible to attain this ideal, but scientists always strive for it....

ACTIVITY 1 - Variables in Observing a Picture

Observe Figure 2, which is constructed with only three sizes of black dots. Do you recognize the object in the picture? Now, prop the page in a vertical position, and as you look at the picture, walk slowly away from it. Keep walking until you can name the object in the picture, and then continue reading.

As you walked away from the picture, you eventually were so far away that the dots appeared to merge into one another and the object in the picture became apparent. At what distance, in metric units, did this occur? Try it again if you didn't notice the distance. The distance at which you first recognized the object can be called a variable--something that was part of the event or situation. Other variables in this example include the color of the wall in the room where you are looking at the picture, the amount of light shining directly on the book, and the quality of your vision.

QUESTION 1

Make a list of the variables that you infer may have an influence on the distance at which you are first able to recognize the object in the picture of Figure 1. Some of these variables are listed in the Comments on Activities, but be sure to make your list before turning to that section.

Suppose you infer that the distance at which the object is just recognizable (resolved) depends on whether you start close to the picture and walk away from it or begin at a long distance away and approach the picture. In this inference, there are two variables. Think about how you could investigate this situation before reading the next paragraph. Then check your plan with the one proposed in the following paragraph, and try your test or the one described.

You could first begin at a distance beyond which the picture is recognized and then move toward it. Measure the distance at which you think you are able to recognize the face. Then begin at a position close to the picture and move away from it. Measure the distance at which you think you are just able to recognize the face in the picture. If the illumination, color, observer, and so on, were unchanged, you should be able to make some statement about the influence of the variable direction of approach on the variable distance at which the face in the picture is recognized.

QUESTION 2

In the test described (or the one you planned yourself), what variables are held constant? That is, were any variables not allowed to change? Which ones?

Which variables were allowed to change? (The direction of your movement in relation to the picture, and the distance from the picture at which you identify the object.) Which of these variables did you manipulate? In the test described above, you walked toward the picture and then away from it. In other words, you manipulated the direction of your motion. The direction is called the manipulated variable. The variable distance is the responding variable.

So far, three kinds of variables have been identified and named: the manipulated variable, the responding variable, and the variables held constant. In the test just described, all of these variables were controlled. How can this be? Certainly the variables

which were held constant were controlled. The manipulated variable was controlled at your will. The responding variable was controlled by the manipulated variable. So, all variables were controlled in the test. Usually, most variables in a test or investigation are held constant, one is manipulated either by design or because it cannot be helped.

QUESTIONS 3 and 4

In manipulating the variable in this example (direction of movement in relation to the picture), only two possible values of this variable were considered. What were they? What other values might have been assigned to this variable?

You have been conducting an investigation in which you manipulated the variable, direction of movement in relation to the picture. Look at the list of variables in this situation (either your list or the one given in the Comments on Activities). What other variable or variables might be tested in order to determine the distance from the picture at which the object could be recognized? Could the amount of light in the room be manipulated as a variable in a different investigation? How about the height of the picture above the floor? The answers to these questions are yes. The questions are asked to emphasize that several variables might have been manipulated. This is not to suggest that more than one variable be manipulated at a time. In elementary classrooms, you should try to restrict investigations to those in which only one variable is manipulated at a time....

COMMENTS ON ACTIVITY

ACTIVITY 1 (QUESTION 1)

1. The distance of the observer from the picture
2. The observer (eyesight, sensitivity or retina, color-blindness)
3. The light in the room
4. The light directly illuminating the picture
5. The color of the light illuminating the picture
6. The direction of approach of the observer to the picture

7. The amount of practice the observer has had

8. Whether or not the observer has recognized the object in the picture prior to determining the distance

ACTIVITY 1 (QUESTION 2)

Variables that should be held constant include illumination on picture, speed of walking, person being tested, position of picture.

ACTIVITY 1 (QUESTIONS 3 and 4)

The two values are walking directly toward the picture and walking directly away from it. You might have walked toward or away from the picture at an angle different from 90° (AAAS, 1970, p. 129 ff.)

A5 - ORGANIZING DATA

General Competency

The student will collect and organize data and describe the rationale for the organization (describing, diagramming, tabulating, graphing, etc.)

Performance Criterion

Given an activity, the student will:

A5.1 collect, organize, and describe the rationale for the organization to the satisfaction of the instructor.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. Read and study "Organizing Data."

2. Complete the activity outlined in the general information related to how water flows or drops. Check your results with those given.

3. Complete the activity "Your Fingers, His Pulse" and/or "The Weight of Our Height." Collect and organize your data. Describe your rationale for this organization. (You may select a comparable activity.)

4. Arrange with your instructor for other activities requiring presentation of data.

5. When you feel that you have met the performance criterion, date and initial your Competency Completion Checklist.

A5 - NOTES AND COMMENTS FOR ORGANIZING DATA

...A graph is a device for communicating a relationship between two variables. In Science--A Process Approach, pupils are introduced to graphing with bar graphs which are particularly useful for recording numbers of different objects. For example, in one hour a bird watcher counted 20 sparrows, 6 robins, 2 cardinals, 1 wren, and 10 starlings. This information can be displayed in a bar graph, as in Figure 3.

Look at Figure 3 carefully and then make your own bar graph. Take some change from your coin purse and count the number of each kind of coin. Then make a bar graph to show the numbers of pennies, nickels, dimes, quarters, and half-dollars.

The two variables that are plotted in Figure 4 and the ones you have just plotted are called discontinuous variables. This means that there are no intermediate values of the variables between the values shown. For example, a bar showing 5.5 quarters would be meaningless since there is no such thing as half a quarter. Likewise there is no coin between a penny and a nickel, or between a nickel and a dime. Both the number of coins and the kind of coins are discontinuous variables. Bar graphs are useful for showing relationships between discontinuous variables.

Line graphs, on the other hand, are useful for communicating relationships between continuous variables. Figure 4, for example, shows the number of swings per minute for pendulums of different lengths. The points with the circles around them show the number pairs that were actually measured. Here the two variables are continuous. There are intermediate values between the points that are plotted. The pendulum can be of any length and there can be any number of swings per minute including fractions of swings such as 30.3. The smooth curve through the points for which number pairs were measured indicates that the variables are continuous. The smooth curve can be used to find number pairs that were not actually measured. For example, the line includes the number pair (85, 33). That is a pendulum 85 centimeters long would swing 33 times in one minute.

One of the skills that you are expected to develop in this exercise is the relationships and trends shown in graphs. Figure 4, for example, indicates that as a pendulum is made shorter it swings more rapidly. The

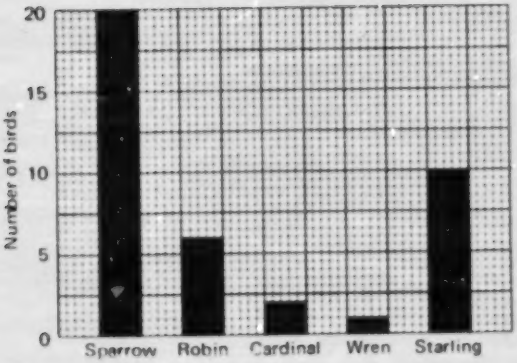

FIGURE 3

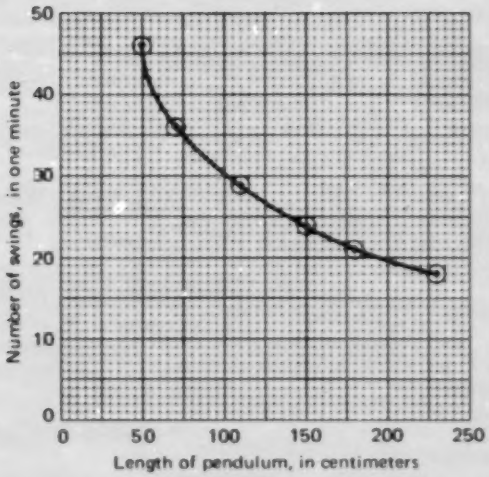

FIGURE 4

change in rate of swing for a given change in length is greater for short pendulums than for long ones. For example, shortening a 200-centimeter pendulum by 10 centimeters increases the rate only one swing per minute. But shortening a 60-centimeter pendulum by 10 centimeters increases the rate more than 7 swings per minute.

Before you begin constructing a point graph, some of the conventions used for constructing graphs in Science--A Process Approach, are identified in the next paragraph. Study the graph (Figure 5) and try to make the correct choices in the statements which follow.

1. The (manipulated, responding) variable is graphed on the horizontal or the x-axis.

2. The (responding, manipulated) variable is graphed on the vertical or y-axis.

3. Each axis (is, is not) labeled so as to describe what was manipulated and what was observed.

4. The intersection of the x-axis with the y-axis (is, is not) the zero-or starting-point of the x and y number lines.

5. The units of measurement of each pair of observations (are, are not) indicated along with the labels on the x-axis and the y-axis.

6. Numerals are placed along each axis at (regular, irregular) intervals as on a number line.

7. The numeral on the y-axis where a horizontal line crosses the y-axis determines the y-coordinate of any point on that horizontal line. (Yes, No)

8. The numeral on the x-axis where a vertical line crosses the x-axis determines the x-coordinate of any point on that vertical line. (Yes, No)

9. The graph (is, is not) a grid formed by horizontal and vertical lines, each line having an assigned value as shown by the numerals along the x-axis and the y-axis.

10. Numerals along each axis are placed (on, between) the vertical and horizontal lines of the grid.

Did you choose the first item of each pair of choices?...

Now try your hand at contructing a graph of data you collect. To collect the data, you will need a paper cup with a flat bottom, a pin, a 100-milliliter graduated container, some water, and a stopwatch or a watch with a second hand. Make a pinhole in the bottom of the cup. Place your finger over the pinhole and fill the cup nearly full of water. Hold the cup so that the pinhole is directly over the 100-milliliter container, remove your finger, and immediately start timing. Rest the cup on the top of the container. Read and record the volume of water in the container every 20 seconds for three minutes. Then make a graph using the number pairs you have collected. Write a short statement describing the relationships of the variables and the trend shown by the graph. When you have finished, compare your graph and statement with the one in the Comments on Activities section....

COMMENTS ON ACTIVITIES

If your change did not contain one kind of coin, for example, half-dollars, you should have marked a place for that coin on your graph. The absence of a bar above it indicates that your change included no coins of that type.

The graph in Figure 5 is a plot of data similar to that which you collected when you measured the water flowing from a pinhole in a paper cup. Note that some of the observed number pairs do not lie on the curve. The curve was drawn as a best fit of the set of number pairs. Notice that of the number pairs that do not lie on the line, approximately half are above and half are below the line. In scientific work, it is generally assumed that deviation of a number pair from a smooth curve indicates an experimental error, such as failing to read the watch dial or the volume scale precisely.

The graph shows that the water flows through the hole fastest at the start and more slowly as time progresses (AAAS, 1970, p. 101 ff.).

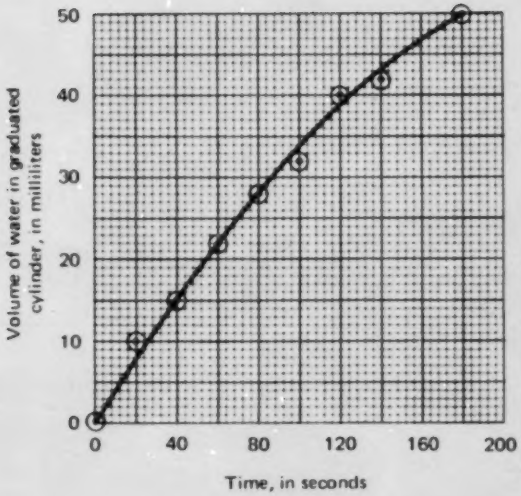
Volume of water in graduated cylinder, in milliliters
50
40
30
20
10
0
0
40
80
120
160
200
Time, in seconds

FIGURE 5

YOUR FINGERS, HIS PULSE

1. Identify a partner for this activity.
2. Calmly sit for three minutes. Have your partner take your pulse with his fingers (not his thumb).
3. Have your partner count your pulse rate for 30 seconds.
4. Wait one minute.
5. Again, have your partner count your pulse rate for 30 seconds.
6. Average the two values obtained.
7. Double the average value and record it. This represents your pulse rate before exercise.
8. Now, run up and down two flights of stairs or do 20 jumping-jacks.
9. Have your partner take your new pulse rate according to steps 3 through 7 above and record it. This is your pulse rate after exercise.
10. Reverse the above procedures with your partner to obtain his pulse rate before and after exercise.
11. Now, obtain the pulse rates of ten other people before and after exercise.
12. Make a graph for each pulse rate variable (before and after exercise) against some other variable (i.e., height, weight, sex, age, time of day, etc...).

THE WEIGHT OF OUR HEIGHT

1. Identify and list the names of the other students in the classroom, each student's height in inches and his weight in pounds.
2. Predict what relationship you could expect between weight and height.

3. Graph the two variables, weight and height (use X for males and 0 for females, or design a procedure of your own).

4. Determine if there is a difference in the weight-height relationship for males and females.

A6 - HYPOTHESIZING

General Competency

The student will construct a hypothesis, test its validity, and on the basis of the results obtained from testing either accept the hypothesis or reject and modify it.

Performance Criteria

Given an experiment and/or data, the student will:

A6.1 construct a hypothesis.

A6.2 test the validity of his hypothesis.

A6.3 accept his hypothesis or reject and then modify it.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. Read and study "Formulating, Testing, and Modifying Hypotheses."
2. Complete the activity, "Activity 1 - Constructing a Hypothesis."
3. Complete the activity, "Activity 2 - Testing a Hypothesis."
4. Construct a hypothesis of your own.
5. Test the validity of your hypothesis.
6. Accept your hypothesis or reject it and, if needed, modify it. State your reasons in writing.
7. When you feel you have met the performance criteria, date and initial your Competency Completion Checklist.

A6 - NOTES AND COMMENTS FOR HYPOTHESIZING

FORMULATING, TESTING, AND MODIFYING HYPOTHESES

Thinking about observations leads scientists to seek causes for events. To broaden their understanding of their environment, they then generalize their statements of explanation. This process of generalization is what we have called Formulating Hypotheses.

In Science--A Process Approach, a hypothesis is defined as a generalization that includes all objects or events of the same class. Hypotheses may be formulated on the basis of observations or of inferences. For example, you may observe that a sugar cube dissolves faster in hot water than in cold water. From such an observation, you might formulate the hypothesis that all substances soluble in water will dissolve faster in hot water than in cold water. An example of a hypothesis that is generalized from an inference is as follows: If you invert a glass jar over a burning candle, the candle will continue to burn for a short time and then go out. One of several inferences that you might make to explain this observation is that the candle went out because all of the oxygen in the air in the jar was used up. A hypothesis based on this inference might be that burning candles covered with glass jars go out when all the oxygen in the jar is used up.

Research scientists devise tests of hypotheses. Testing a hypothesis that is a generalization from observations consists of making more and more observations of whatever class of objects or events is covered by the hypotheses. For example, the hypothesis that all substances soluble in water will dissolve more quickly in hot water than in cold water can be tested only by mixing many substances that are soluble in water with both hot and cold water and recording their dissolving times. If any substance is found to dissolve in hot water at the same rate as, or more slowly than, in cold water, then the hypothesis is not supported.

Testing a hypothesis that is a generalization from an inference also involves conducting a test which will provide data that will support or not support the hypothesis. In the case of the hypothesis about burning candles under glass jars, it is necessary to test the air in the jar after the candle has gone out to see whether or not oxygen is present. This experiment has been conducted and oxygen is indeed present even after the candle has gone out, so the hypothesis is not supported.

When data are collected that do not support a hypothesis, the hypothesis must either be modified or rejected. In the case of the hypothesis about the dissolving time of substances soluble in water, if some few exceptions are found, the hypothesis might be revised to say: Most substances soluble in water will dissolve more quickly in hot water than in cold water. The hypothesis about burning candles might be modified to state: Candles under inverted jars go out when the amount of oxygen in the air in the jar is reduced to 10%. Or, it might be replaced by a new hypothesis, such as: Candles under inverted jars go out when the amount of carbon dioxide in the air in the jar increases to 3%. All of these hypotheses could be tested by further investigations.

ACTIVITY 1 - Constructing a Hypothesis

In the exercise Viscosity, Experimenting 11, Exercise p, Part G, the children observe the apparatus shown in Figure 6. Each of the vials is full of a liquid, and each contains an object that appears to be ellipsoidal. The caps of the vials are fastened firmly into holes in a wood strip. When the vials are inverted, as in Figure 7, the objects fall through the liquids at different rates. Some of the observations that may be made are:

1. The object in Vial A falls fastest and the one in Vial B slowest.

2. The object in Vial A is red, in Vial B, green, and in Vial C, blue.

3. The vials have the same shape and size. The liquids are colorless.

4. Each vial has a small air bubble in it. The air bubbles move up as the objects move down. The bubble in A rises most rapidly, and the bubble in B least rapidly.

QUESTION 1

Write several inferences that might account for these observations. After you have made your inferences, generalize one of them into a hypothesis. As you construct your hypothesis, keep in mind that you are going to construct and demonstrate a test of it in Activity 2.

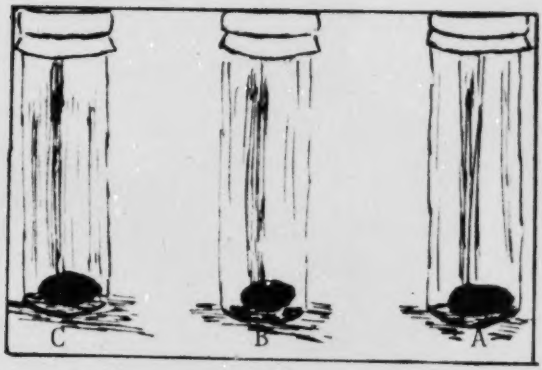

FIGURE 6

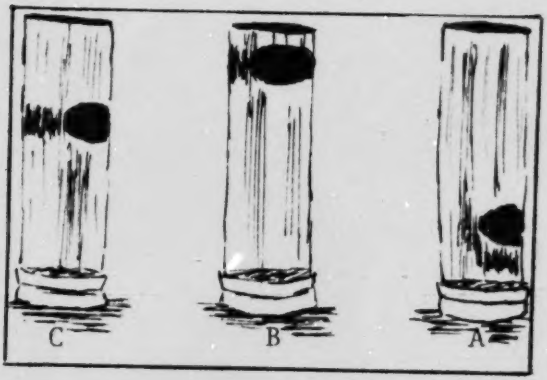

FIGURE 7

QUESTION 2

What you do in this activity depends entirely on what hypothesis you constructed in Activity 1. Your hypothesis will also determine what materials you will need to carry out your test. You will almost certainly need screw or snap cap plastic vials and one or more liquids (water, corn syrup, cooking oil, and so on). Objects you may want to try might include marbles of various sizes, metal spheres (shot), and pebbles.

Plan and execute your test carefully. Remember that for best results, you should control all variables. You should identify the manipulated and responding variables, and plan to hold all other variables constant.

After you have carried out your test and collected and recorded your data, you should interpret your data and decide whether or not your observations support or do not support your hypothesis. If your hypothesis is not supported, revise it to take account of your new observations. When you have completed the activities, read the following Comments on Activities.

COMMENTS ON ACTIVITIES

ACTIVITY 1 (QUESTION 1)

There are many inferences you might make. Here are a few:

1. The objects have different masses. The object in A is the heaviest and the object in B is the lightest of the three.

2. Though the objects appear to have approximately the same size, their size actually differ a little. Object B is the smallest and object A is the largest of the three.

3. There is a different liquid in each vial. The liquid in B is thickest and that in A is the thinnest.

Each of these inferences could be generalized into a hypothesis. Here is a hypothesis from Inference 1: The rate at which an object falls through a liquid depends on its mass. Given two objects of the same size but different mass, the heavier one will fall through a particular liquid faster than the lighter one.

ACTIVITY 2 (QUESTION 2)

Suppose you want to test the following hypothesis. Objects of the same size, shape, and mass fall faster in thin liquids than in thick ones.

The manipulated variable is the thinness or thickness of the liquid. These terms are not commonly used by scientists to describe properties of liquids, though they are frequently heard in everyday speech. They should be defined operationally at the time that the test of the hypothesis is being constructed. Here is one possible operational definition:

> Pour 50 milliliters of the liquid into a 100-milliliter beaker. Invert the beaker and hold it upside down for 10 seconds. Right it and measure the amount of liquid that remains in the beaker. The greater the amount of liquid remaining, the thicker the liquid.*

To test the hypothesis, prepare three or more solutions of different viscosities. These might be water, and 10%, 20%, and 30% sugar solutions. Test the solutions and order them by viscosity. Take four identical vials and fill each with one of the solutions. Then, take four identical marbles and place one in each vial. Screw the cap on each vial. Invert the vials and compare the rates at which the marbles fall through the liquids. If the rate of fall is slower in the more viscous liquids, the hypothesis is supported. If not, the hypothesis will have to be revised or discarded (AAAS, 1970 pp. 157-161).

---

*This is a rough measure of a property of liquids called viscosity. The more viscous the liquid, the more slowly it flows from a container.

A7 - REPLICATING

General Competency

The student will replicate an experiment and compare the results obtained with those in the original experimentation.

Performance Criteria

Given an experiment, the student will:

A7.1 replicate the experiment

A7.2 compare the results with those obtained in the original experiment.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. Arrange with the instructor to obtain an experiment.

2. Conduct this experiment according to the information given.

3. Record your data. Compare in writing the results you obtained with those in the original experimentation.

4. When you feel that you have met the performance criteria, date and initial your Competency Completion Checklist.

A7 - NOTES AND COMMENTS FOR REPLICATING

GUIDELINE B

Science for elementary teachers should be taught in the same style of open inquiry that is encouraged in elementary science programs. The student's science experience should result in his enthusiasm for and confidence in teaching science through inquiry to children.

INSTRUCTIONAL SKILLS

B 1 IDENTIFYING AND CLASSIFYING MEASURABLE PERFORMANCE OBJECTIVES - The student will be able to identify measurable objectives and classify them into categories according to Bloom's Taxonomy of Educational Objectives.

B 2 COMPREHENDING THE BASIC PRINCIPLES OF INQUIRY (DISCOVERY) TEACHING - The student will demonstrate his comprehension of the basic principles of inquiry (discovery) science teaching.

B 3 DESIGNING AND CONSTRUCTING AN INQUIRY ACTIVITY MODULE - The student will be able to construct an inquiry (discovery) teaching module which contributes to both the product (content) and the process aspects of science.

B 4 TEACHING BY MEANS OF INQUIRY OR DISCOVERY - The student will demonstrate his ability to use the inquiry (discovery) approach with a group of peers and/or pupils.

SELF-EVALUATION--PROGRESS SCALE

In order to determine your present competency level for instructional skills, please read the competencies B1 through B4. Place a "B" in the appropriate column to indicate your beginning competency level.

At the end of the course, place an "E" in the appropriate column to indicate the degree of competency you feel you possess. This self-evaluation will enable you to visualize your growth toward the attainment of each competency.

	I have no knowledge of this competency.			I am familiar with the competency and feel I have an adequate understanding of the concept.			I fully understand the competency and can utilize and/or relate it to my science teaching.		
	1	2	3	4	5	6	7	8	9
B1									
B2									
B3									
B4									

B1 - IDENTIFYING AND CLASSIFYING MEASURABLE PERFORMANCE OBJECTIVES

General Competency

The student will be able to identify measurable objectives and classify them into categories according to Bloom's Taxonomy of Educational Objectives.

Performance Criteria

Given a set of statements, some of which are measurable objectives, the student will:

B1.1 identify those which are measurable, with at least 80% accuracy.

B1.2 classify the measurable objectives into categories based on Bloom's Taxonomy of Educational Objectives in the cognitive domain, with at least 80% accuracy.

Instructions for Completing the Competency

The following instructions provide a recommended sequence in completing this competency:

1. Read the enclosed set of statements and identify which are measurable.

2. Record your responses, as well as your confidence level, on the response sheet provided by the instructor.

3. Evaluate your responses and compute your confidence level. See instructor.

4. Read enclosed materials entitled "Taxonomy of Educational Objectives in the Cognitive Domain."

5. Using the measurable objectives you have identified from the statements, classify them into the six categories.

6. When you feel that you have met the performance criteria, date and initial your Competency Completion Checklist.

B1 - NOTES AND COMMENTS FOR IDENTIFYING AND CLASSIFYING MEASURABLE PERFORMANCE OBJECTIVES

STATEMENTS

1. Given the ESS booklet on Colored Solutions, the student will read the booklet carefully and have a better understanding of various salt solutions.

2. Given a meter stick, the student will be able to select the appropriate units for making a particular measurement to the satisfaction of the teacher.

3. Given a set of objects, the student will group objects or systems of objects according to a given property.

4. Given the textbook, the student will develop an appreciation for the meaning of Ohm's law.

5. Using a metric scale, the student will weigh three objects and grasp the significance of the scale to the satisfaction of the teacher.

6. Using a hygrometer, the student will list the steps in their order for setting up and reading a hygrometer.

7. Given a classroom situation, the prospective teacher will teach an activity and be committed to teaching as a career.

8. Given an experiment, the student will distinguish between dependent and independent variables with 100% accuracy.

9. Given a unit on evolution, the student will have faith in the theory of evolution to the satisfaction of the instructor.

10. Without the aid of references, the student will know exactly what to do in case of a science classroom emergency.

11. Given an ESS activity, the student will devise and use simple means of checking the accuracy of his predictions.

12. The student will be able to identify the factor most likely to have caused a given change in a system.

Statements (contd.)

13. Given an experiment, the student will orally recognize which data are necessary and sufficient to support an inference or a generalization to the satisfaction of the instructor.

14. With the aid of reference materials, the student will appreciate and believe that a hypothesis is a basis for generalizing in terms of similar problem situations.

15. Given a selected experiment, the student will use a planned procedure insolving the problem.

16. Given a completed activity, the student demonstrates that he is slow to accept facts which are not supported by data.

17. Given an outdoor activity, the student will enjoy it and believe that children should be taken outside regularly.

18. The student will develop an appreciation for science and grasp its impact on our country.

19. With the aid of selected materials, the student will recognize in writing and use pertinent arguments, reasons, or principles to justify a prediction.

20. Given a laboratory situation, the student will become familiar with and have respect for chemicals in the classroom.

TAXONOMY OF EDUCATIONAL OBJECTIVES IN THE COGNITIVE DOMAIN

1.0 KNOWLEDGE

This involves the recall of specifa, processess, or structure. It is often a rote procedure with little, if any, alteration of material.

A description of the behavior expected of the student would be to:

a. define	d. identify
b. recall	e. list
c. recognize	f. name

2.0 COMPREHENSION

This involves understanding of the literal message contained in a communication. It includes the ability to translate, interpret and extrapolate.

A description of the behavior expected of the student would be to:

a. translate	d. summarize
b. make inferences	e. draw conclusions
c. predict	f. generalize

3.0 APPLICATION

This level involves the ability to use abstractions in concrete/real situations. The abstractions could be general ideas, rules, methods, concepts or theories which need to be remembered and applied.

A description of the behavior expected of the student would be to:

a. apply	d. illustrate
b. demonstrate	e. use
c. employ	f. solve

4.0 ANALYSIS

This involves the breakdown of material into organizational or necessary parts so that the relation among parts is clear. The breakdown should illuminate the basis and organization of the material.

A description of the behavior expected of the student would be to:

a. classify (group)
b. identify elements (parts)
c. detect (fallacies, casual relations, etc.)
d. organize
e. explain
f. relate

5.0 SYNTHESIS

This involves putting together parts to form a whole. This process combines the parts or elements to form a structure that is new to the student.

A description of the behavior expected of the student would be to:

a. integrate
b. propose
c. design
d. plan
e. organize
f. formulate

6.0 EVALUATION

This involves making judgments in terms of the available material or external evidence, based on appropriate standards or criteria.

A description of the behavior expected of the student would be to:

a. compare (using a standard)
b. distinguish
c. assess
d. rank
e. critique
f. appraise

B2 - COMPREHENDING THE BASIC PRINCIPLES OF INQUIRY (DISCOVERY) TEACHING

General Competency

The student will demonstrate his comprehension of the basic principles of inquiry (discovery) science teaching.

Performance Criteria

Given appropriate situations provided by the instructor, the student will discuss in writing subject matter related to such topics as:

B2.1 the nature and purposes of discovery or inquiry teaching.

B2.2 advantages and disadvantages of the discovery approach to teaching.

B2.3 the role of the teacher in planning, questioning and using invitations to discovery (such as discrepant events).

B2.4 the role of students in activities, investigations, experiments, questioning, verbalizing, etc.

B2.5 uses of divergent and convergent questioning techniques.

B2.6 appropriate learning theories in science education.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. See the instructor for bibliographic references necessary to meet performance criteria.
2. Read appropriate materials.
3. Complete your discussion in writing and/or schedule a conference with your instructor.
4. When you feel that you have met the performance criteria, date and initial the Competency Completion Checklist.

B2 - NOTES AND COMMENTS FOR COMPREHENDING THE BASIC PRINCIPLES OF INQUIRY (DISCOVERY) TEACHING

B3 - DESIGNING AND CONSTRUCTING AN INQUIRY ACTIVITY MODULE

General Competency

The student will be able to construct an inquiry (discovery) teaching module which contributes to both the product (content) and the process aspects of science.

Performance Criteria

Given the necessary resource materials the student will:

B3.1 select a concept, principle, (or closely related concepts and principles) as a goal for working with children in science. He shall also select at least one of the process skills of science related to the development of the chosen content goal.

B3.2 construct at least one specific measurable objective appropriate to developing the concept and/or principle stated in the goal and at least one such objective appropriate to developing the process skill(s) outlined in the goal statement.

B3.3 plan an invitation to discovery to use as a means of inviting investigative inquiry and activities on the part of the pupils involved in learning the above chosen goal.

B3.4 develop a series of learning strategies (or activities) which along with the objectives and invitation to discovery will comprise an instructional module on the product-process goal.

B3.5 construct sample convergent and divergent questions to use in teaching the above module. The questions will be used to stimulate investigating and generalizing on the part of the pupils.

B3.6 develop tasks (or other means) to assess the accomplishment of the objectives (B3.2) set up for the module.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. "sing the available resources in the classroom and/or the curriculum laboratory identify a concept or principle (or closely related concepts or principles) as the overall goal for your teaching module.

2. Construct at least one specific measurable objective for the content and at least one for the process(es) stated in your goal.

3. Schedule a conference with your instructor.

4. Design an invitation to discovery to introduce your teaching module.

5. Develop a series of learning strategies (or activies) for the objectives which you have developed for your teaching module.

6. Construct sample convergent and divergent questions to use in teaching your module.

7. Develop evaluation tasks to assess the children's achievement of the objectives you have identified for your module.

8. When you feel that you have met the performance criteria, date and initial the Competency Completion Checklist.

B3 - NOTES AND COMMENTS FOR DESIGNING AND CONSTRUCTING AN INQUIRY ACTIVITY MODULE

B4 - TEACHING BY MEANS OF INQUIRY OR DISCOVERY

General Competency

The student will demonstrate his ability to use the inquiry or discovery approach with a group of peers and/or pupils by teaching part (or all) of the instructional module he developed in B3.

Performance Criterion

Given a simulated or real teaching situation, the student will:

B4.1 demonstrate his ability to teach the module which he has developed to the satisfaction of the instructor and/or a panel of judges.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. Schedule time with instructor for teaching the module.

2. See the instructor to arrange for him or a panel of judges to evaluate your teaching experience.

3. When you feel that you have met the performance criterion, date and initial the Competency Completion Checklist.

B4 - NOTES AND COMMENTS FOR TEACHING BY MEANS OF INQUIRY OR DISCOVERY

GUIDELINE C

Science experiences should be selected so as to develop a capacity and disposition for continuous learning which the teacher should demonstrate by engaging in science activities which will provide new information and experiences capable of affecting existing attitudes, ideas, and teaching.

INTEREST AND RESEARCH/CURRICULUM KNOWLEDGE

C 1 DEMONSTRATING INTEREST - The student will demonstrate an interest in teaching science to children.

C 2 DEMONSTRATING KNOWLEDGE - The student will demonstrate his knowledge of the nature of science.

C 3 DESCRIBING AND COMPARING PROGRAMS - The student will describe and compare selected activity-based science programs.

C 4 ANALYZING CHILDREN'S RESPONSES - The student will present and analyze children's responses to Piagetian-type tasks.

SELF-EVALUATION--PROGRESS SCALE

In order to determine your present competency level for science interest and curriculum/research knowledge, please read the competencies C1 through C4. Place a "B" in the appropriate column to indicate your beginning competency level.

At the end of the course, place an "E" in the appropriate column to indicate the degree of competency you feel you possess. This self-evaluation will enable you to visualize your growth toward the attainment of each competency.

	I have no knowledge of this competency.			I am familiar with the competency and feel I have an adequate understanding of the concept.			I fully understand the competency and can utilize and/or relate it to my science teaching.		
	1	2	3	4	5	6	7	8	9
C1									
C2									
C3									
C4									

C1 - DEMONSTRATING INTEREST

General Competency

The student will demonstrate an interest in teaching science to children.

Performance Criterion

During the academic period, the student will:

C1.1 read a minimum of three (3) current science-related articles (one or more from the journal, Science and Children), read one (1) or more books which deal with teaching science and will show evidence of his reading in his course notebook.

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. Select recent articles and book(s) available in science education center, curriculum laboratory, university library, and bookstore.

2. React (in writing or orally) to the material you have read.

3. Enter in your notebook bibliographical data on articles and book(s) read.

4. When you feel that you have met the performance criterion, date and initial your Competency Completion Checklist.

C1 - NOTES AND COMMENTS FOR DEMONSTRATING INTEREST

C2 - DEMONSTRATING KNOWLEDGE

General Competency

The student will demonstrate his knowledge of the nature of science.

Performance Criteria

In response to appropriate situations set up by the instructor, the student will be able to demonstrate in writing that he comprehends the meaning of:

C2.1 the nature of science

C2.2 concepts, principles, and conceptual schemes

C2.3 processes of science

C2.4 scientific methodology

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. See the instructor for bibliographic references necessary to meet performance criteria.
2. Read appropriate material.
3. Complete your discussion in writing and/or schedule a conference with your instructor.
4. When you feel that you have met the performance criteria, date and initial the Competency Completion Checklist.

C2 - NOTES AND COMMENTS FOR DEMONSTRATING KNOWLEDGE

C3 - DESCRIBING AND COMPARING PROGRAMS

General Competency

The student will describe and compare selected activity-based science programs.

Performance Criterion

Provided access to adequate sampling of materials in activity-based elementary science programs the student will:

C3.1 describe and compare these programs: S-APA, ESS, SCIS, MINNEMAST and COPES.

Instructions for Completing Competency

1. Classify the above programs according to their emphasis on the product (content) of science and/or the processes of science.

2. Select any three (3) of these programs and compare their structure or organization (i.e., fields of science covered, age levels, sequence, teacher's guides, other pertinent aspects).

3. Select one (1) part (booklet, section, unit) from each of the above three (3) programs and briefly describe its nature and why it interested you.

4. When you feel that you have met the performance criterion, date and initial the Competency Completion Checklist.

C3 - NOTES AND COMMENTS FOR DESCRIBING AND COMPARING PROGRAMS

SELECTED ACTIVITY-BASED SCIENCE PROGRAMS

The following activity centered projects have received considerable attention during the past ten years. They are representative of recent curriculum movements in science education at the elementary school level. Additional information and materials can be obtained from your instructor or by writing to the publishers of the programs.

SCIENCE CURRICULUM IMPROVEMENT STUDY (SCIS)

Science Curriculum Improvement Study (SCIS) developed by the University of California, Berkeley and supported by the National Science Foundation:

Publisher

Rand McNally and Company
School Department
Box 7600
Chicago, Illinois 60680

Materials

1. Teacher's Guides - A manual for each unit which contains information to help the teacher.

2. Student Manuals - The student manual is used by children to record information about their experiments. Some of the primary units do not have manuals.

3. Unit or Equipment Kit - Each contains the equipment and materials needed for 32 pupils to perform the activities in the program.

4. Films - Teaching and inservice films may be purchased or rented. Extension Media Center
   2223 Fulton Street
   Berkeley, Calif. 94720

Level - K-6

Description

The Science Curriculum Improvement Study (SCIS) consists of two series of related and sequential life science and physical science units for each of the six

levels. Children are introduced to knowledge of scientific content through individual and group investigations. Through these activities, they engage in observation, measurement, interpretation, prediction, and other processes. The program presents four major scientific concepts: matter, energy, organism and ecosystem. Performance objectives for each of the twelve units have been developed for the program. No student textbooks are available.

ELEMENTARY SCIENCE STUDY (ESS)

Elementary Science Study (ESS) developed by Educational Services Incorporated and supported by the National Science Foundation.

Publisher

Webster Division
McGraw-Hill Book Company
Manchester Road
Manchester, Missouri 63011

Materials

1. Teacher's Guides - Each of the 56 units has a guide which provides background information, teaching suggestions, activities, illustrations, a description of the materials needed in teaching, and ideas for integrating the material into other areas of the curriculum.

2. Student Materials - These worksheets, individual cards and booklets provide guides for making or assembling equipment, reading material and pictures and procedures for recording observations made in the classroom.

3. Equipment and Materials Kits - Each classroom kit contains the equipment and materials needed for 30 children. Small group kits for 6 children and individual study are also available for some units.

4. Film Loops and Films - The film loops can be used by a whole class, a small group, or an individual student. Films (16 mm.) are available for some units; teacher-training or inservice films are also available.

Level - K-9

Description

Elementary Science Study (ESS) consists of more than 56 individual teaching units, each of which may be used for varying lengths of time in a range of grades. The units are open-ended. Several units may be selected for a complete science program or individual units may be identified to supplement a program already in use. It is not necessary to purchase a kit for each unit since much of the material needed for teaching can be obtained locally. There are no student textbooks. Performance objectives are not available.

SCIENCE--A PROCESS APPROACH (S-APA)

Science--A Process Approach (S-APA), developed by the American Association of the Advancement of Science - Commission on Science Education and supported by the National Science Foundation.

Publisher

Ginn and Company
191 Spring Street
Lexington, Massachusetts 02173

Materials

1. Commentary for Teachers - A self-instructional text of units in workbook form for teachers.

2. Hierarchy Charts - These charts visually represent the organization and objectives of the program.

3. In-Service Training Materials - These consist of an in-service guide, response booklets, process measures and kit materials.

4. Comprehensive Classroom Units (Kits) - Each unit contains the equipment and materials needed for 30 pupils to perform the activities in the program.

Level - K-6

Description

Science--A Process Approach (S-APA) is an activity-centered program which involves all learners in the processes of science (i.e., Observing, Using Space/Time Relationships, Measuring, Interpreting Data, etc...). The activities are designed to teach scientific processes and concepts. No student textbooks are available S-APA is a competency based structured program, providing group and individual performance measures for each set of activities (booklets).

CONCEPTUALLY ORIENTED PROGRAM IN ELEMENTARY SCIENCE (COPES)

Conceptually Oriented Program in Elementary Science (COPES) developed by the COPES Project at New York University and supported by the U. S. Office of Education and the National Science Foundation.

Publisher

New York University
School of Education
Center for Field Research and School Services
51 Press Building
Washington Square
New York, New York 10003

Materials

1. Teacher's Guides - Self-instructional texts which contain the appropriate activities, and a hierarchy of science concepts to be presented to children at each grade level (K-6).

2. Assessment Kits - Each kit contains unbound concept assessment pages and worksheets for each grade level.

Level - K-6

Description

Conceptually Oriented Program in Elementary Science provides a highly-structured, sequentially organized elementary science program for children. The program centers on five conceptual schemes (i.e., conservation of energy, interaction and change, etc...). Since each

scheme is too comprehensive to be presented as a whole, the program concentrates on examples of the concepts that will lend themselves to progressive ordering or sequencing to enable children to understand each scheme. Performance objectives and concept goals are included in the teacher's guides; there are no textbooks for children.

MINNESOTA MATHEMATICS AND SCIENCE TEACHING PROJECT (MINNEMAST)

The Minnesota Mathematics and Science Teaching Project (MINNEMAST) developed by the University of Minnesota and supported by the National Science Foundation.

Publisher

MINNEMAST
720 Washington Avenue, S.E.
Minneapolis, Minnesota 55455

Materials

1. Teacher's Guides - A manual for each unit which contains teaching suggestions, activities and worksheets for the teacher.

2. Student Manuals - The student manual contains activities and worksheets for the program.

3. Equipment Kit - Each kit contains the equipment needed for 30 children. Information on where to obtain these is available from the publisher.

Level - K-3

Description

The Minnesota Mathematics and Science Teaching Project (MINNEMAST) consists of more than 29 teachers' guides and handbooks. The project developed a coordinated science and mathematics curriculum for primary children. The unifying idea of the program is the study of systems. This concept is developed through the study of objects and their classification. It stresses the processes of science through group and individual experiences with concrete materials. Several of the initial units are appropriate for pre-school children. No student textbooks are available.

C4 - ANALYZING CHILDREN'S RESPONSES

General Competency

The student will present and analyze children's responses to Piagetian-type tasks.

Performance Criterion

Given the text entitled Student-Structured Learning in Science the student will:

C4.1 read and complete "Section 4.1, Studying the Child's Interpretation of His Environment."

Instructions for Completing Competency

The following instructions provide a recommended sequence in completing this competency:

1. Read "Studying the Child's Interpretation of His Environment."

2. Prepare the necessary materials.

3. Arrange to interview six or more children (i.e., two 7-year-olds, two 9-year-olds, and two 11-year-olds or any similar combination).

4. Tabulate and evaluate the results of the study.

5. Compare all task results obtained and specify what implications the findings have for elementary curriculum. When all students have completed the tasks the instructor will tabulate the results. These results will be used as a basis for discussion.

6. When you feel you have met the performance criterion, date and initial the Competency Completion Checklist.

BIBLIOGRAPHY

American Association for the Advancement of Science. Preservice Science Education of Elementary School Teachers: Guidelines, Standards, and Recommendations for Research Development. A Report sponsored by the AAAS Commission on Science Education and supported by the National Science Foundation. AAAS, 1970.

American Association for the Advancement of Science. Science--A Process Approach: Commentary for Teachers. Third experimental edition. AAAS, 1968.

American Association for the Advancement of Science. Science--A Process Approach: Commentary for Teachers. AAAS/Xerox Corporation, 1970.

Carin, Arthur A., and Robert B. Sund. Teaching Modern Science. Columbus, Ohio: Charles E. Merrill Publishing Company, 1970.

Matthews, Charles C., Darrell G. Phillips, and Ronald C. Good. Student-Structured Learning in Science: A Program for the Elementary School Teacher. Dubuque, Iowa: Wm. C. Brown Company Publishers, 1971.

Stone, A. Harris, Fred Geis and Louis Kaslan. Experiences for Teaching Children Science. Belmont, California: Wadsworth Publishing Company, 1971.

Sund, Robert B., and A. J. Picard. Behavioral Objectives and Evaluational Measures: Science and Mathematics. Columbus, Ohio: Charles E. Merrill Publishing Company, 1972.